Hydrological responses to volcanic strain and the arising capabilities for volcano monitoring

Many volcanic processes are associated with crustal deformation. Because of their poroelastic nature, aquifers in volcanic regions respond to the applied strain with changes in pore pressure and groundwater flow patterns. These variations are mirrored in well water levels, which can therefore provide important constraints on the subsurface processes causing the deformation.

We developed numerical models that simulate crustal deformation due to different volcanic strain sources and the dynamic poroelastic aquifer response with finite element analysis. The models are applied to two case studies. The first investigates possible deformation sources for strain-induced well level changes by up to 10 m preceding the 2000 eruption of Usu volcano (Japan). We propose that these were induced by the pressurization of both the magma chamber at 4 km depth and a large, shallow hydrothermal system.

The second case study simulates water level changes in the Belham valley on Montserrat over the course of two years (2004-2006). In this case, the aquifer responds to both gradual and rapid transient strain sources associated with the eruption of Soufrière Hills volcano (Montserrat). Repeated lahar sedimentation in the valley leads to a steadily increasing sediment load and thereby rising aquifer pressures. The wholesale dome collapse in May 2006 on the other hand induced significant dilatational strain and thereby a short-term water level drop.

The presented models are a significantly improved tool for the interpretation of well level signals in volcanic areas that can provide valuable constraints for volcanic strain sources and thereby complement other monitoring systems.